Low Tension Panel (LT) Reliability Analysis

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Abstract—Low tension panel is electrical distribution board that receives power from generator or transformer and distributes the same to various electrical and electronics devices and distribution boards such panels are used in industries, domestics' applications. LT Panel will play critical role in the continuity of the electrical supply for the load appliances like fans, motors etc to provide luxury life for the human being. In this panel different type of switch gear equipment are used such as Bus Coupler, Air Circuit Breaker (ACB), Miniature Circuit Breaker (MCB), Relays, Switches and Fuses. The major failures such as over voltages, under voltage, over load and over currents will leads to reduce the performance of this panel. Low tension panel manufacturing process is mainly intended to bring out the process issues and failure modes using reliability tool PFMEA concepts and also evaluate the reliability of this panel by using MIL-STD-217F.

Keywords: PFMEA, RPN, Failure Rate, MTBF, Reliability, MIL-STD-217F

I. INTRODUCTION

Manufacturing defects or errors are always the key concerns of any manufacturing industry. The success of any organization depends on the quality of product especially right product produced, for this much care need to be taken at the designing stage of the product. This manufactures LT panels, MV panels, C&R panel, PCC panel and distribution board and chargers and IPS. The initial research shows the past trends of rejection is between 8-9% which includes human error in material removal, wrong fitting of component, lack of awareness on material handling, skipping of defects, etc. the need is to reduce that to compete in highest competitive market and to continuous satisfaction of customer. One of the successful tools for finding the failure mode and its effect in manufacturing process is PFMEA (Process failure mode effect analysis). By Process FMEA we can find out how critical the process is and we can take action to reduce the failure in product and improve the manufacturing process.The performance of the system is calculated by Reliability parameters such as Failure rate and MTBF and these are evaluated using MIL standards 217F.

II. PROCESS OF MANUFACTURING STUDY

In this Chapter LT Panel treated as a System comprising of some components. Several companies are manufacturing Low Tension panel for electrical supply and distributes power to various electrical and electronics devices and distribution board. LT panel mainly consist of three sections such as Incomers, Sub-incomers, Feeders. After manufacturing of individual parts they get assembled and then whole product can be supplied to the customers. Manufacturing accuracy should be needed for the reliable operation of LT panel if any discrepancy present in the standard manufacturing process will lead to the solid damage to economical condition of the organization and customer dissatisfaction.

2.1 COMPONENTS

Incoming section has Incoming Bus-bars, Air Circuit Breaker (ACB), Sub-incoming section consists of Monitoring devices such as LEDs, Meters and Protection devices like Relays, Rotary Switches, Miniature Circuit Breaker (MCB), and HRC Fuses. Feeder section has Feeder Bus-bars.

Bus-bars:

The bus bars shall be air insulated and made of high quality and high conductivity, high strength aluminum. The interconnection between bus bars and various components shall be high conductivity aluminum. The bus bars shall have uniform cross-section throughout the length. The bus bars and interconnections shall be insulated with heat shrinkable PVC sleeve and be colour coded is red, yellow, blue and black to identify the three phases and neutral of the LT panel.

Air Circuit Breaker:

Air circuit breakers, which are usually employed for the protection of electrical equipment's with tripping coil connected to a relay designed to open the breaker automatically under abnormal conditions, such as over current, over load, over loads etc. Air Circuit Breaker provides the short circuit, over load, earth fault protection of LT panel.

Miniature Circuit Breakers:

A miniature circuit breaker (MCB) is a small circuit breaker that is used for domestic and industrial applications. It has two functions such as

- switching function
- Protection function

Switching function: Switching Function of the MCB allows the connection/disconnection of the LT panel.

Protection function: Protection Function of MCB must isolate the LT panel in the event of over currents and over load and short circuits.

LEDs:

LED stands for light emitting diode. These are mainly used for making indicators and various other types of lightning. InLEDelectrical energy is converter in to optical energy. These are example of electroluminescencethe main advantages of using these are the low energy consumption, longer lifetime, strong build, smaller size etc.Today almost everywhere LEDs lights are used and the application of LED is huge.Indicators and signs: these are mainly used in meters, indication lamps, traffic signals, exit signs, light weight message, displaying box etc.

Meters:

These meters are digital type. These are multi functioning meters. It should measure KW, KVA, KVAR, V, I, PF etc.

Relay:

A relay is automatic device which senses an abnormal condition of LT panel and close its contacts. These contacts in turns close and complete the circuit breaker trip coil LT panel hence makes the circuit breaker tripped for disconnecting the fault part of LT panel from the rest of the healthy section.

Switches:

A switch is used in LT panel as a device for making or breaking the electric circuit. The switches may be classified into this panel such as Rotary switch and push button.

HRC Fuses:

HRC fuses or high rupturing capacity fuses. In these types of fuse, the fuse wire or element can carry fault current for known time. During of this time the fault is cleared, then it does not blow or melts otherwise it melts.

2.2 PROCESS FLOW CHART

Process Flow Chart describes step by step process of the manufacturing process of the LT panel from work allotment to the production section to Dispatch to the Customer.

The Fig.1 presenting the process flow chart for LT panel

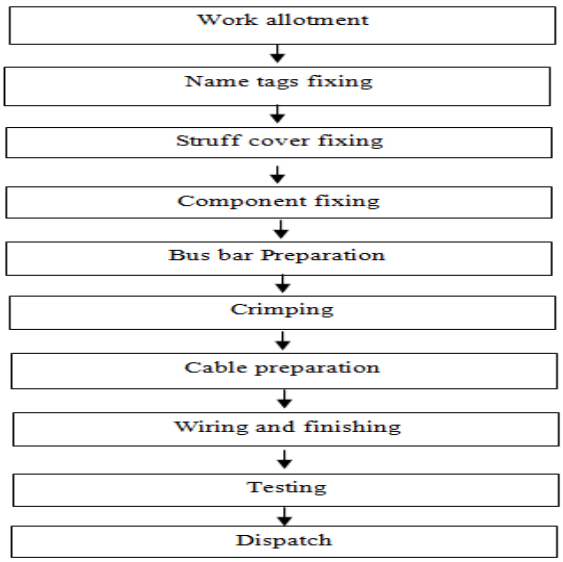

Fig. 1: Process Flow Chart of LT panel Manufacturing

III. FAILURE MODE AND EFFECT ANALYSIS

There are several types of failure modes occurred in the area of LT Panel, Which are mainly categorized as critical and non critical failures depending up on the risk level of those failures on the system. Failure mode and effect analysis need to be done to know the effect of failures and appropriate actions need to be taken to reduce the risk level to increase the performance of the LT panel.

There are mainly two types FMEA methods**,** Design and Process Failure mode and effect analysis.

- **DFMEA:**Used to analyze a product design before it is released to manufacturing.
- **PFMEA:** Used to analyse Manufacturing and Assembly process. Both Quality and Reliability may be affected from process faults or failures.

For analyzing the failure modes and its consequent effects in the manufacturing stages of LT panel are analyzed by using Process FMEA.

3.1 PROCESS FMEA

Process FMEA is a systematic approach for identification potential failure mode occurred in the manufacturing process of LT panel. Process FMEA for Low Tension panel steps is given below.

- Define the problem
- Analyze the problem

- Generate possible solutions
- Select the best solution
- Plan for implement the best solution
- Evaluate the solution

IV. CALCUALTION OF RPN

RPN is the important factor to know the risk level of the several failure modes of a component or system. Calculation of RPN based on conducted PFMEA. RPN is calculated by knowing three terms of the failure modes, those are Severity, Occurrence, and Detection. Process FMEAconducted for monitoring of manufacturing process from work allotment level to visual inspection level and calculated some risk priority number from raised failure modes step by step process of production section. The general formulae for calculate RPN as given below.

RPN = Severity* Occurrence* Detection

Few of the RPN values of failure modes are calculated based on the predefined formulae and the values given in Table.1

Table.1 RPN values for potential failure modes

Process steps	Failure Mode	Effect	Severity	occurrence	detection	RPN
Component fixing	Wrong Component	Functional failure	8	6	5	240
Visual inspection	Skipping of defects	Functional failure	7	6	5	210
Bus bar preparation	Lapping and bolting of Bus bars are improperly fitted	Aesthetic appearance	7	7	6	294
Bus bar preparation	Wrong shape and dimensions	Improper bending and punching of holes	8	7	5	240
Component fixing	Wrong rating material may be fixed	Functional failure	8	6	5	240
Visual inspection	Aesthetic defect	Improper fixing	7	7	5	245

RPN Valuesof Different Failure modes in the process steps of the manufacturing process, which are known by conducting PFMEA on the system and necessary action, need to be taken to improve the performance of the system.

In the Fig.2 Initial RPN values and RPN values after the improvement action taken are given.

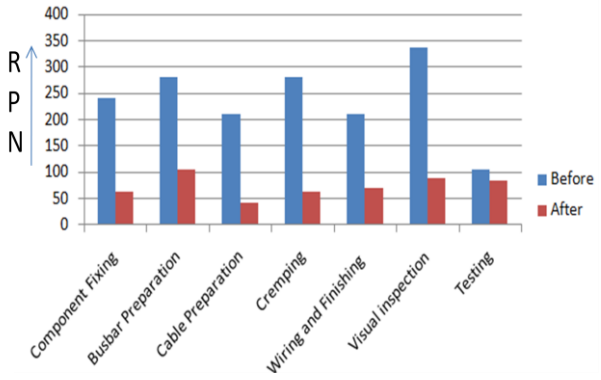

Fig. 2: RPN Values of the Different Failure Modes

V. PARAMETERS EVALUATION OF LT PANEL USING MIL-STD-217F

Failure rates, MTBF and Reliability of LT Panel can be calculated by using MIL-STD-217F. Definitions of terms are

Failure Rate:

Every product has a failure rate, λ which is the number of units failing per unit time. This failure rate changes throughout the life of the product.

$$\text{Failure rate} = \frac{\text{no .of failures}}{\text{totla time}} \quad \text{(failure/10\^6 hr)}$$

MTBF:

The expectation of the operating time between failures, when the failure rate is constant with times the operating times between failures are exponentially distributed. This leads to

$$\text{MTBF} = \frac{1}{\lambda} \qquad \ldots (1)$$

Or

$$\text{MTBF} = \frac{\text{totla time}}{\text{no .of failures}} \text{ hr}$$

Simple says that reciprocal of failure rate of components.

Reliability:

A practical definition of reliability is "the probability that a piece of equipment operating under specified conditions shall perform satisfactorily for a given period of time". The reliability is a number between 0 and 1.

- Assume the failure rate of component is constant.

$$r(t) = e^{-\lambda t} \qquad \ldots (2)$$

Here

λ= total failure rate of LT panel (in FPMH)

t= operating time in hours

For the Evaluation of Parameters, considering the standard formulae and values of electrical and electronicsComponents from MIL-STD-217F. The list of parameter failure rates and MTBF values are calculated based on the Environment, Quality Temperature and Configuration Factors and Base Failure rate of respective Components. List of Components shown below and Failure rate and MTBF are calculated from the Formulas given below.

1. **Air Circuit breaker:**

In this panel air type circuit breakers are used. And failure rate prediction of circuit breaker is mathematical product of base failure rate and environment, quality, utilization and configuration factors. And calculation of mean time between the failures is reciprocal of part failure rate of circuit breaker. The mathematical representation of equations as shown below, using MIL-

STD-217F standard values substitute below equation and get the part failure rate of circuit breaker.

From MIL-STD-217F (Notice1&2)

$\lambda p = \lambda b * \pi c * \pi q * \pi u * \pi e$ .... (3)

Here

λ_p = Part failure rate

λ_b = Base Failure Rate

π_c = Configuration Factor =1.0 for SPST, 2-for DPST, 3-TPST,4-for 4PST

π_q = Quality Factor

π_u = Utilization Factor

π_e = Environmental Factor

MTBF= 1/Part Failure rate= $1/\lambda_p$

2. Connections:

In this panel there are different type of connection are used mainly considering the terminal blocks. Calculating the failure rate of connection is product of base failure rate and environmental factor of terminal blocks. And also calculate the mean time between the failures of connection using predefined formulae.

$\lambda p = \lambda b * \pi e$ (4)

3. LED'S:

In this panel LED's are used for indication purpose. Calculating the failure rate of LED is product of base failure rate and temperature, quality and environmental factors. And also calculate the mean time between the failures of connection using predefined formulae.

$\lambda p = \lambda b * \pi t * \pi q * \pi e$ … (5)

4. Fuses:

In this panel there are different type of fuses are used mainly considering the HRC fuses. Calculating the failure rate of fuses is product of base failure rate and environmental factor of fuses. And also calculate the mean time between the failures of connection using predefined formulae.

$\lambda p = \lambda b * \pi e$ ... (6)

5. Meters:

In this panel there are different type of meters are used for measuring purpose. Meters are AC or DC based on the application. Calculating the failure rate of meters is product of base failure rate and environmental factor, application, quality and function factors of meters. And also calculate the mean time between the failures of meters using predefined formulae.

$\lambda p = \lambda b * \pi e * \pi q * \pi a * \pi f$ … (7)

6. Relays:

In this panel relays are played vital role for protection of panel from abnormal conditions, calculate failure rate of relays is mathematical product of base failure rate and load stress, cycle, function, configuration, quality and environment factors.And also calculate the mean time between the failures of relays using predefined formulae.

$\lambda p = \lambda b * \pi l * \pi c * \pi cyc * \pi f * \pi q * \pi e$ … (8)

7. Switches:

In this panel two types of switches are used such as rotary switch and push button. Calculate failure rate of switches is mathematical product of base failure rate and load stress, configuration, quality and environmental factors of switches. And also calculate the mean time between the failures of switches using predefined formulae

$\lambda p = \lambda b * \pi l * \pi c * \pi q * \pi e$ … (9)

And also calculation had done for reliability evaluation of LT Panel. By using Exponential distribution we may also calculating the reliability of Low Tension Panel at different operating or serving time.

➢ Assume the failure rate of component is constant.

$$r(t) = e^{-\lambda t}$$

Here

λ= total failure rate of LT panel (in FPMH)

t= operating time in hours

VI. RESULTS

Prediction result of LT panel is shown Table.2given below

Table. 2 Failure rate and MTBF values of components

Name: LT PANEL FR: 2.23236 f/10^6 hr MTBF: 447956.4 hr. Analyst: RAJESH S				
S.NO	*Components/Description*	*Quantity*	*Failure Rate*	*MTBF*
1	Air Circuit Breaker	1	1.36	735294.12
2	Connections	1	0.062	1612903
3	LED's	1	0.00038	26315789
4	Fuses	1	0.0099999	1000000
5	Meter, Panel	1	0.5202	1922337
6	Relay	1	0.28224	3543083
7	Switches	1	0.002545	3928964

Reliability of LT Panel is calculated at different operating time or servicing time as shown below given Table.3

Table.3 Reliability of LT Panel at different operating times

RELIABILTY OF LOW TENSION PANEL BASED ON THE DIFFERENT OPERATING OR SERVING TIME	
OPERATING TIME	RELIABILITY OF LT PANEL
t=1000hr	0.997765136
t=8760hr	0.980591500
t=87600hr	0.822012784
t=100000hr	0.799525781

From the failure rate of components plot the Fig.3 where failure rates of components LED, switches and fuses are negligible and highest failure rates are meter, circuit breaker and relays are observed from Fig .3

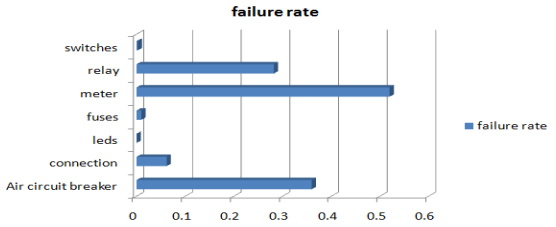

Fig.3Failure rates of Components

Performance characteristics of LT Panel is drawn between reliability of system to number of operating time in hours, from the Fig.4 understood that number of operating time is increase, the reliability of the system is decreases.

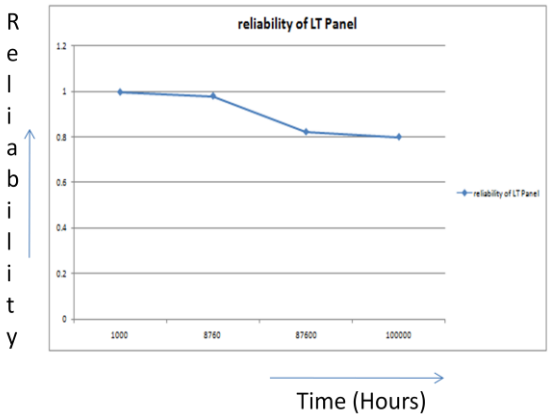

Fig.4 Performance characteristics of LT Panel

VII. CONCLUSION

In this paper, PFMEA analysis had done for Low Tension (LT) Panel and for the identification of the failure modes in the manufacturing process of Low Tension panel and also reliability prediction had done for evaluation of failure rate, MTBF and reliability of the Low Tension Panel. The performance is assessed by using MIL-STD-217F.So many manufacturing industries using Process FMEA analysis for their improvement strategy for quality of products and organization. With the help of bill of material of Low Tension panel, performance characteristics such as Failure rate, MTBF and Reliability are calculated manually and also their nature with time also explained with graphs. Finally theoretically calculated and simulated results from software are presented.

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